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## Phase I: Greenhouse Bench-Scale Test

Thomas C. Sturgis, Charles R. Lee, and
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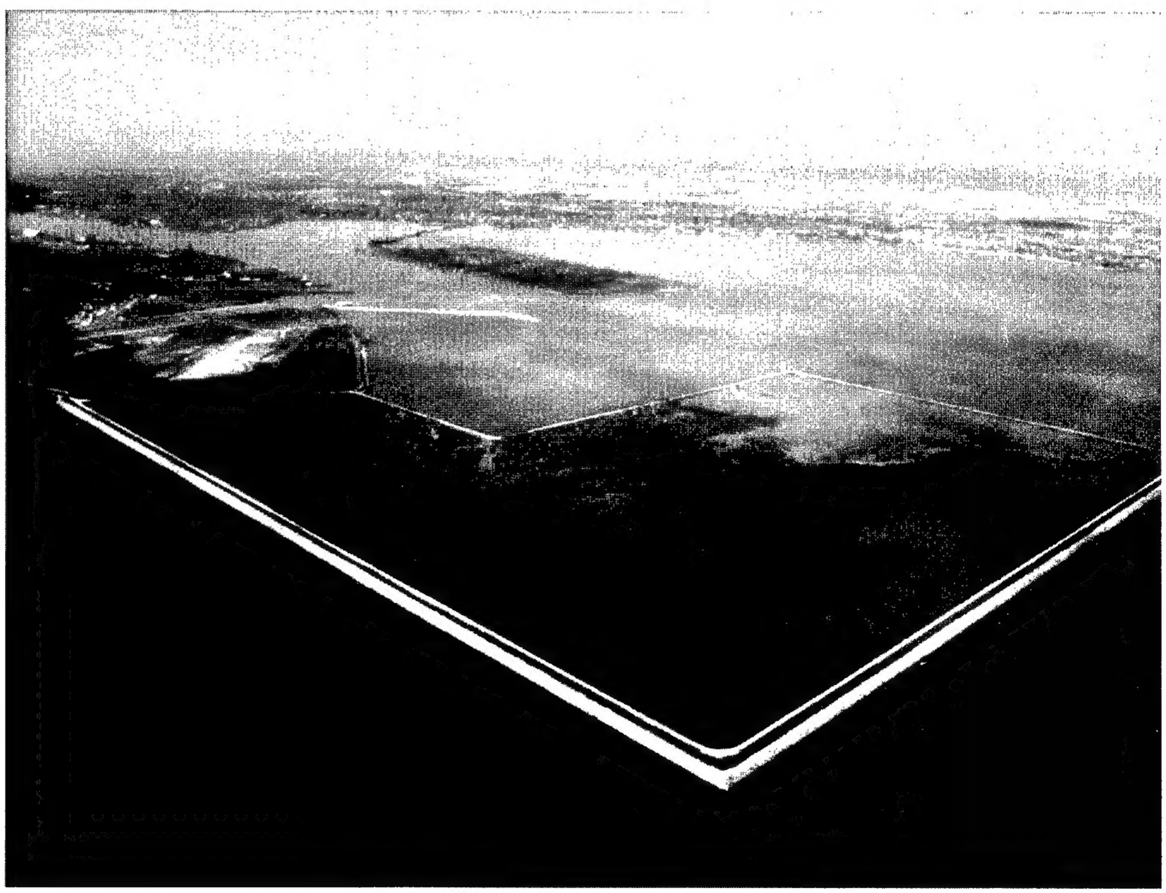
September 2001



Environmental Laboratory

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# Evaluation of Toledo Harbor Dredged Material for Manufactured Soil

## Phase I: Greenhouse Bench-Scale Test

by Thomas C. Sturgis, Charles R. Lee

Environmental Laboratory
U.S. Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Henry C. Banks, Jr.

Dyntel Corporation
3530 Manor Drive, Suite 4
Vicksburg, MS 39180

Final report



Prepared for U.S. Army Engineer District, Buffalo
Buffalo, NY 14207-3199

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# Preface

This report describes work performed by the U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS. This study was sponsored by the U. S. Army Corps of Engineers, Buffalo District, Buffalo, NY, under a civil works reimbursable project.

The study was conducted and the report prepared by Drs. Thomas C. Sturgis and Charles R. Lee, Environmental Risk Assessment Branch (ERAB), Environmental Processes and Effects Division (EPED), Environmental Laboratory (EL), ERDC. Mr. Henry C. Banks, Jr., Dyntel Corporation, provided assistance in preparing and conducting the laboratory/greenhouse screening tests.

The study was conducted under the direct supervision of Mr. Lance Hansen, Chief, ERAB, and under the general supervision of Dr. Richard E. Price, Chief, EPED, and Dr. Edwin A. Theriot, Acting Director, EL.

At the time of publication of this report, Dr. James R. Houston was Director of ERDC, and COL John W. Morris III, EN, was Commander and Executive Director.

This report should be cited as follows:

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# Executive Summary

Dredged material is the result of soil erosion and surface runoff from terrestrial environments. Soil particles, along with other materials in runoff, find their way to the bottom of waterways. These soil particles become sediment that eventually needs to be removed from the waterways to maintain navigation. The U.S. Army Corps of Engineers (USACE) is responsible for maintaining navigable waterways and annually dredges approximately 400 million $m^3$ of sediment. Finding sites for dredged material is becoming difficult, since most confined placement facilities (CPFs) are at full capacity. Likewise, sewage sludge can no longer be placed in the ocean; consequently, sewage sludge is piling up on land at many sewage-treatment facilities. Also, large volumes of sewage sludge are currently placed in landfills; however, landfills are filling at accelerated rates. To resolve the accumulation and placement of sewage sludge, the U.S. Environmental Protection Agency (USEPA) has issued 40 CFR Part 503 regulations (USEPA 1990, 1993, 1995). The regulations promote the reuse of biosolids derived from sewage sludge and establish maximum limits for metals in soils amended with biosolids derived from sewage sludge for agricultural production. These limits are based on risk-assessment evaluations (USEPA 1989).

To address both the excess of dredged material and sewage sludge, the U.S. Army Engineer Research and Development Center (ERDC) Environmental Laboratory, Vicksburg, MS, began to evaluate the potential for manufacturing artificial soil from dredged material and organic wastes. Cooperative Research and Development Agreements (CRDAs) were established with commercial companies to develop the technology for manufacturing soil from dredged material. The recycled soil manufacturing technology offers a quick, simple, low-technology, effective, and affordable means of allowing the reuse of dredged material, provides additional placement capacity for future dredged material by emptying many existing full CPFs, and recycles waste materials to the benefit of the American people.

Screening tests (seed germination and plant growth) were used in Phase 1 of the recycled soil manufacturing technology to evaluate the feasibility of manufacturing soil using dredged material from Toledo Harbor Cell 1 placement facility. Screening tests included proprietary blends with a range of dredged material content, a range of cellulose content, and N-Viro biosolids.

*a.* *Seed germination screening test.* Tomato, marigold, vinca, and ryegrass were tested following procedures developed by a nationally known bagged soil products company. Percent seed germination was highest in proprietary Blend 2 consisting of dredged material from Toledo Harbor Cell 1, cellulose, and N-Viro biosolids. Even though percent germination was highest in proprietary Blend 2, ryegrass percent germination was highest in proprietary Blends 3 and 1. Results after 21 days paralleled results obtained in the 14-day germination test. The additional time did, however, enhance percent seed germination.

*b.* *Extended plant growth test using manufactured soil blends.* A 7-week plant growth screening test was conducted using the same experimental design as the seed germination study. Visual observation of leaf color, size, shape, and total aboveground biomass was used to evaluate the influence of the different manufactured soil blends on plant growth. Results from Phase 1 testing showed that the highest biomass was obtained from proprietary Blend 4. Evaluation of the plant aboveground biomass data also showed that proprietary Blend 4 produced plant growth comparable to the fertile reference control (commercial bagged soil product). Therefore, proprietary Blend 4, consisting of dredged material from Toledo Harbor Cell 1 CPF blended with cellulose and N-Viro biosolids, appears very promising as a manufactured soil product.

# 1 Introduction

## Background

The U. S. Army Corps of Engineers (USACE) Buffalo District, under authority of Code of Federal Regulations (CFR) for navigation and navigable waters, 33 CFR 337.9 (Part 200 to the end), is responsible for identifying and developing dredged material placement management strategies for long-term needs for Toledo Harbor, OH, and for implementing the National Environmental Policy Act 33 CFR 233 and 40 CFR 1501.7 to determine the scope and significance of issues related to proposed actions. This long-term management strategy (LTMS) is also conducted under authority provided by Section 356 of the Water Resources Development Act (WRDA) of 1992 (WRDA 1992), which directed the development of a comprehensive sediment management strategy for the Maumee River, Toledo, OH.

To develop an LTMS for Toledo Harbor, a 5-year Memorandum of Agreement (MOA) was signed in 1986 by the USACE, the Ohio Environmental Protection Agency, the Toledo Metropolitan Area Council of Government, the Toledo-Lucas County Port Authority, and the City of Toledo.

The LTMS had five phases:

*a.* Phase 1. Evaluate Existing Management Options

*b.* Phase 2. Formulate Alternatives Plans

*c.* Phase 3. Preliminary Analysis of Alternatives, Recommend for Approval and Implementation, an Action Plan having an Interim Plan as a component

*d.* Phase 4. Implement the LTMS that includes execution of the Interim Plan

*e.* Phase 5. Implementation, Periodic Review, and Update of the LTMS

Phases 1, 2, and 3 have been completed, and an Action Plan containing an Interim Plan has been recommended. One alternative recommended in the Action Plan is manufactured soil/beneficial reuse of Toledo Harbor dredged material. The Port Authority was given the lead to develop this alternative as NU-Soil for Island 18 confined placement facility (CPF). The U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS, was asked

to develop a fertile manufactured soil product using dredged material from Toledo Harbor Cell 1 CPF for bagged soil and landscaping industries. To accomplish this task, ERDC conducted manufactured soil screening tests, using its cooperative research and development agreements (CRDAs) with commercial companies who were interested in using Toledo Harbor dredged material as an ingredient for their manufactured soil products. For example, Scott and Sons Company has a requirement for 4 million cu yd of silt each year for their bagged soil product. The CRDA allows ERDC and Scott and Sons Company to screen suitable dredged material for use in bagged soil products. The CRDAs will enable the recycled soil manufacturing technology to be developed at USACE confined placement sites. Established or pending CRDAs are listed in the following tabulation:

| Cooperating Companies | Aspect of Manufactured Soil |
|---|---|
| Scott and Sons Company* | Bagged soil products |
| Recycled Soil Manufacturing Technology (RSMT) (formerly Terraforms) | Formulation and blending equipment |
| N-Viro International | Reconditioned biosolids from sewage sludge |
| BION Technologies, Inc.* | Reconditioned biosolids from cow manure |
| *Pending | |

The recycled soil manufacturing technology (RSMT) is site specific. The optimal blend for a specific dredged material will depend on the physical and chemical characteristics of that dredged material and the available cellulose and biosolids. The proprietary blend found productive for one site may not be similar to dredged material, cellulose, and biosolids from other sites. Therefore, bench-scale tests should be conducted on individual dredged material. Following successful bench-scale tests of the recycled soil manufacturing technology, either demonstration, pilot-scale or large-scale, should be conducted, or commercialization of the technology should be developed by the CRDA partners and local interests. Since there are proprietary restrictions placed on describing the specific amount and nature of each ingredient that makes up the manufactured topsoil product, implementation and application of the recycled soil manufacturing technology will require contacting appropriate ERDC Environmental Laboratory scientists and/or obtaining license from Mr. Paul Adam, the patent holder.

## Purpose and Scope

The purpose of this report is to present results of bench-scale screening tests conducted by the ERDC Environmental Laboratory and additional bench-scale screening tests performed by Scott and Sons Company at its research facility in Marysville, OH. These tests were the first such screening tests of dredged material from Toledo Harbor Cell 1 CPF and therefore were to indicate the feasibility of using the dredged material for manufactured soil products. Limited characterization of the dredged material was also obtained. The best formulation of dredged material, cellulose, and N-Viro biosolids was determined and recommended for a pilot-scale field demonstration at Toledo, OH.

# 2 Materials and Methods

## Collection of Dredged Material

Samples of dredged material used in this study were collected from Cell 1 (Site 1) on 20-21 June 1994 and on 19 July 1995 (Figures 1, 2, and 3). Sites 2 and 3 also found within Cell 1 were only collected in June 1994 (Figures 4 and 5). Dredged material core samples were collected using a 4-in.-diam auger with a 4.57-m (15-ft) extension rod. The extension rod allowed dredged material samples to be taken down to a depth of 4.57 m (15-ft) (Figures 6, 7, 8, and 9). Dredged material samples were collected in June 1994 at depths of 0-1.22 m (0-4 ft), 1.22-2.44 m (4-8 ft), and 2.44-3.66 m (8-12 ft). However, dredged material samples collected in July 1995 were at intervals of 0-0.91 m (0-3 ft), 0.91-1.83 m (3-6 ft), 1.83-2.74 m (6-9 ft), and 2.74-3.66 m (9-12 ft). Dredged material samples were collected, placed in 1-L glass jars, stored in a 32-qt cooler, and then transported to ERDC, Vicksburg, MS.

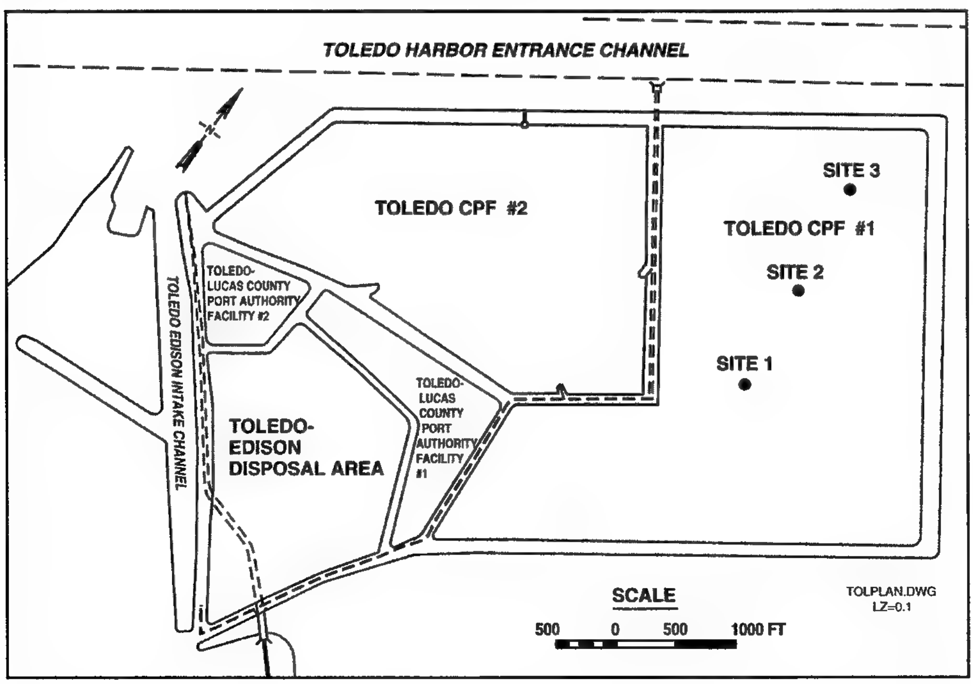


Figure 1. Diagram showing locations of all three sites within Toledo Harbor Cell 1 CPF

Figure 2. Overall view of Site 1 (heavily vegetated) located within the Toledo Harbor Cell 1 CPF

Figure 3. Toledo Harbor Cell 1 CPF – Site 1, 20 June 1994

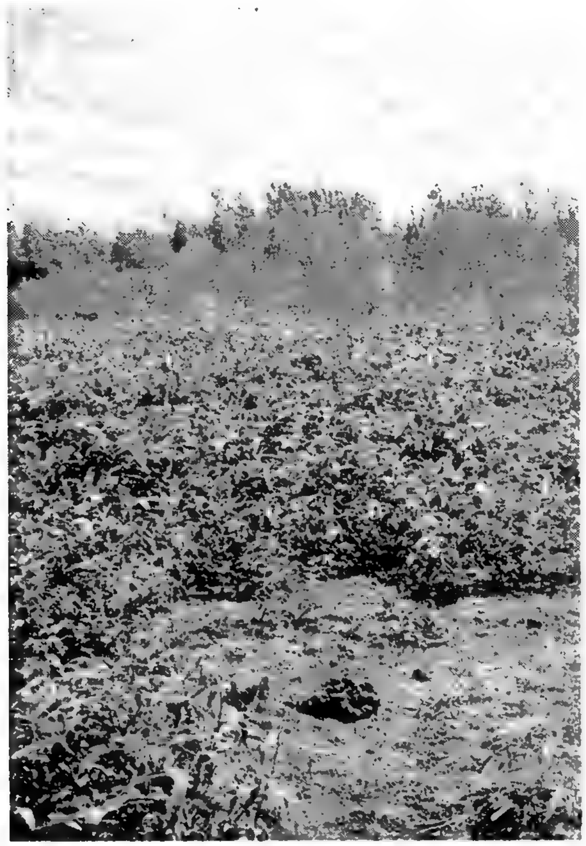

Figure 4. Toledo Harbor Site 2 located midway across Cell 1 CPF, 21 June 1994

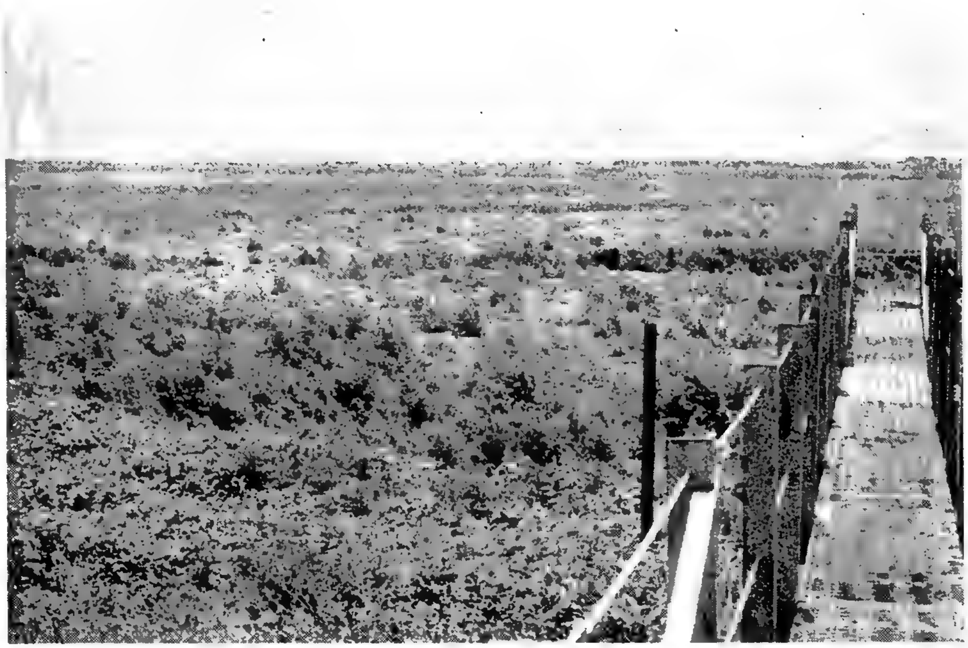

Figure 5. Toledo Harbor Site 3 located near weir, 21 June 1994

Figure 6. Dredged material collected at 3.66-m (12-ft) depth

Figure 7. Dredged material sampling using soil auger

Figure 8. Soil auger with extension rod and handle

Figure 9. Bulk dredged material samples collected from Site 1 wooded area

Upon arrival at ERDC, Vicksburg, MS, the dredged material samples were stored at 4 °C and, later, prepared for chemical characterization. Wet conditions at Sites 2 and 3 precluded sample collection in 1995. Large bulk samples of dredged material from Site 1, collected at the 0 to 0.91-m (0 to 3-ft) depth, were collected in 1995 and transported to Scott and Sons Company at Marysville, OH, and the ERDC, Vicksburg, MS. Scott and Sons Company used this material to conduct their screening tests to evaluate feasibility of using dredged material as an ingredient in their bagged soil product.

## Manufactured Soil Bench-Scale Screening Tests, Seed Germination and Plant Growth

Manufactured topsoil screening tests (seed germination and plant growth) using modified procedures of a national bagged soil product company were used to evaluate the feasibility of manufacturing topsoil from Toledo Harbor dredged material from Cell 1 for beneficial use for landscaping. These tests included various blends of dredged material, cellulose, and N-Viro biosolids. Through CRDAs with Scott and Sons Company and with N-Viro International, a new N-Viro biosolid product with a pH of 7.0 was specifically produced for Toledo Harbor dredged material. A specific blend was prepared by placing the

appropriate amounts of cellulose and N-Viro biosolids in a Twin Shell Dry Blender model LB-10317 and mixing for 5 min. Toledo Harbor dredged material from Cell 1 was then added and mixed an additional 5 min. This process was repeated until all blends were prepared.

Tomato, vinca, marigold, and ryegrass (four annual plant species) were grown from seed in the various blends to evaluate seed germination and plant growth (Table 1). These plants are sensitive to salt, metals, and nutrient imbalances and represent a wide spectrum of upland plants. Tomato, marigold, and vinca seeds were obtained from Ball Seed Co., Chicago, IL, and shipped to ERDC, Vicksburg. Ryegrass seed was purchased from Warrenton Farm and Garden Center, Vicksburg, MS.

**Table 1**
**Toledo Harbor Screening Tests Experiment Design**

| |
|---|
| **Treatments** |
| Blend 1: Toledo Harbor dredged material |
| Blend 2: Toledo Harbor dredged material + cellulose + N-Viro biosolids |
| Blend 3: Toledo Harbor dredged material + cellulose + N-Viro biosolids |
| Blend 4: Toledo Harbor dredged material + cellulose + N-Viro biosolids |
| Blend 5: Fertile reference control |
| **Plant Species** |
| 1. *Lycopersicon esculentum* (Tomato-Big Boy) |
| 2. *Tagetes patula* (Marigold) |
| 3. *Lolium multiflorum Lam.* (Ryegrass-Gulf Annual) |
| 4. *Catharanthus roseus* (Vinca) |
| **Experiment Design** |
| **Seed Germination Test** |
| 5 treatments × 4 species × 3 replicates split-plot design |
| 5 flats × 4 species × 3 replicates |
| **Plant Growth Test** |
| 5 treatments × 4 species × 4 replicates completely randomized block design |
| 5 × 4 × 4 = 80 pots (10-cm pots) |

Five 4.2- × 8.22- × 1.02-cm plastic trays lined with a sheet of plastic were used for seed germination. Each blend was added separately to each tray to a depth of approximately 5.08 cm (2 in.). Three rows of 10 tomato seeds, 10 vinca seeds, 10 marigold seeds, and 20 ryegrass seeds were planted in the same tray containing each manufactured soil blend. All trays were watered when necessary, and seeds were allowed to germinate in the greenhouse under lights providing a day length of 16 hr. The temperature in the greenhouse was maintained at 32.2 ± 5 °C during the day and 21.1 ± 5 °C at night. Emerged seedlings were counted after 14 and 21 days to determine mean germination percentages.

A 7-week plant growth test, using manufactured soil blends similar to those used in the seed germination test, was conducted concurrently with the seed germination test. Eighty 10-cm (4-in.) pots with 10-cm (4-in.) saucers were used to evaluate the growth and appearance of the developing plants in the different blends. All 10-cm pots were prepared by placing a number 42 Whatman™ filter paper in the bottom of each pot to prevent the loss of soil. Each blend was then added separately to each prepared 10-cm pot to approximately 1.27 cm (0.5 in.) from the rim. Three tomato seeds, 3 marigold seeds, 3 vinca seeds, and 20

ryegrass seeds were added separately to each blend. Table 1 shows the experimental design used in the screening tests.

All seeded pots and trays were placed in a randomized block design with four blocks on tables under lights in the greenhouse. Lights were arranged in a pattern of alternating high-pressure sodium lamps and high-pressure multi-vapor halide lamps which provided an even photosynthetic active radiation (PAR) distribution pattern of 1200 $u$Einsteins/m$^2$/sec and a day length of 16 hr. The temperature in the greenhouse was maintained at 32.2 ± 5 °C during the day and 21.1 ± 5 °C at night. Relative humidity was maintained as close to 100 percent as possible, but never less than 50 percent.

Plants, except for the ryegrass, were thinned to one plant per pot when more than one seed germinated in a pot. Where no seeds germinated in pots, plant seedlings were removed from the germination trays or from another 10-cm pot having more than one plant and transplanted to the pot of a corresponding manufactured soil blend. Plant seedlings were then allowed to grow and develop to evaluate plant growth and appearance. After 7 weeks, plants were observed, photographed, and harvested from the various blends. The plant material was cut and washed to remove any soil particles and then blotted to remove excess water. The plant material was bagged, weighed, dried, and reweighed to determine fresh and dry biomass.

# 3 Statistical Analysis

Experimental data were analyzed using analysis of variance (ANOVA) procedures of the Statistical Analysis System (SAS Institute, Inc. 1994). Tests of normality were performed using the Shapiro-Wilf statistic, and homogeneity of variance was evaluated using the Levene's Test. Comparisons of means were performed using the Duncan's Multiple Range Test. In this report, statements of statistical significance without specific indication of probability level refer to $P<0.05$.

# 4 Results and Discussion

## Dredged Material Characterization

The concentration of the various organic and inorganic chemicals in the dredged material collected in 1994 and 1995 from Toledo Harbor Cell 1 Site 1 CPF are shown in Tables 2, 3, 4, and 5. Even though the soil depth intervals were different from 1994 to 1995, analyses were very similar. Dredged material samples (1994) were also collected from Sites 2 and 3 and were analyzed to complete the chemical characterization of dredged material from Toledo Harbor Cell 1 CPF. The results of those analyses showed that all three sites within Cell 1 CPF were very similar (Tables 2, 3, 4, and 5). The manufactured soil using Toledo Harbor Cell 1 dredged material can be used unrestrictedly for any landscaping purpose (USEPA 1993, 1995).

**Table 2**
**Toledo Harbor CPF Cell 1 Pesticide Concentrations 1994-1995 (mg/kg)**

| Parameters | 94 Site 1 0-4 ft | 95 Site 1 0-3 ft | 94 Site 1 4-8 ft | 95 Site 1 3-6 ft | 95 Site 1 6-9 ft | 94 Site 1 8-12 ft | 95 Site 1 9-12 ft | 94 Site 2 0-4 ft | 94 Site 2 4-8 ft | 94 Site 2 8-12 ft | 94 Site 3 0-4 ft | 94 Site 3 4-8 ft |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ALDRIN | <0.0019 | <0.0019 | <0.0019 | <0.0018 | <0.0018 | <0.0017 | <0.0018 | 0.0039 | <0.0075 | <0.0075 | <0.0075 | <0.0075 |
| A-BHC | <0.0014 | <0.0014 | <0.0015 | <0.0014 | <0.0014 | <0.0013 | <0.0013 | <0.0075 | <0.0075 | <0.0075 | <0.0075 | <0.0075 |
| B-BHC | <0.0029 | <0.0027 | <0.0030 | <0.0027 | <0.0028 | <0.0026 | <0.0027 | <0.0075 | <0.0075 | <0.0075 | <0.0075 | <0.0075 |
| G-BHC | <0.0019 | <0.0019 | <0.0019 | <0.0018 | <0.0018 | <0.0017 | <0.0018 | 0.0013 | <0.0075 | <0.0075 | <0.0075 | 0.0014 |
| D-BHC | <0.00044 | <0.00043 | <0.0045 | <0.00041 | <0.00042 | <0.00042 | <0.00040 | <0.0075 | <0.0075 | <0.0075 | <0.0075 | <0.0075 |
| PPDDD | 0.0041 | 0.0041 | 0.0078 | 0.0067 | 0.0081 | 0.0078 | 0.0084 | 0.0035 | 0.0058 | 0.0082 | 0.0038 | 0.0034 |
| PPDDE | 0.0063 | 0.0064 | 0.0069 | 0.0069 | 0.0068 | 0.0059 | 0.0064 | 0.0062 | 0.0069 | 0.0070 | 0.0054 | 0.0047 |
| PPDDT | 0.013 | 0.012 | 0.017 | 0.018 | 0.028 | 0.013 | 0.016 | 0.0023 | 0.0037 | 0.0038 | 0.0026 | 0.0025 |
| HPTCL | <0.0014 | <0.0014 | <0.0015 | <0.0014 | <0.0014 | <0.0013 | <0.0013 | <0.011 | <0.011 | 0.0032 | <0.011 | 0.0011 |
| DIELDRIN | <0.00096 | <0.00094 | <0.00098 | 0.0060 | 0.0059 | <0.00087 | <0.00089 | <0.0075 | <0.0075 | <0.0075 | <0.0075 | <0.0075 |
| ENDOI | <0.0067 | <0.0065 | <0.0068 | <0.0063 | <0.0065 | <0.0061 | <0.0062 | <0.0075 | <0.0075 | <0.0075 | <0.0075 | <0.0075 |
| ENDOII | <0.0019 | <0.0019 | <0.0019 | <0.0018 | <0.0018 | <0.0017 | <0.0018 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 |
| ENDOSU | <0.032 | <0.031 | <0.0033 | <0.030 | <0.031 | <0.029 | <0.030 | <0.015 | <0.015 | 0.00099 | <0.015 | <0.015 |
| ENDRIN | 0.0026 | 0.0022 | 0.0037 | 0.0051 | 0.0030 | 0.0034 | 0.0033 | 0.0047 | <0.023 | <0.023 | 0.0040 | 0.0038 |
| ENDALD | <0.011 | <0.011 | 0.0020 | <0.010 | 0.0021 | 0.0016 | 0.0018 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 |
| HPTCLE | <0.039 | <0.038 | <0.040 | <0.037 | <0.038 | <0.036 | <0.036 | <0.0075 | <0.0075 | <0.0075 | <0.0075 | <0.0075 |
| METOXYCL | <0.084 | <0.083 | <0.086 | <0.079 | <0.081 | <0.077 | <0.078 | <0.0075 | 0.0080 | <0.0075 | <0.0075 | 0.0053 |
| CLORDANE | <0.0067 | <0.0065 | <0.0068 | <0.0063 | <0.0065 | <0.0061 | <0.0062 | <0.0075 | <0.0075 | <0.0075 | <0.0075 | <0.0075 |
| TOXAPHEN | <0.11 | <0.11 | <0.12 | <0.11 | <0.11 | <0.10 | <0.11 | <0.015 | <0.15 | <0.15 | <0.15 | <0.15 |

## Table 3
## Toledo Harbor CPF Cell 1 PAH Concentrations 1994-1995 (mg/kg)

| Parameters | 94 Site 1 0-4 ft | 95 Site 1 0-3 ft | 94 Site 1 4-8 ft | 95 Site 1 3-6 ft | 95 Site 1 6-9 ft | 94 Site 1 8-12 ft | 95 Site 1 9-12 ft | 94 Site 2 0-4 ft | 94 Site 2 4-8 ft | 94 Site 2 8-12 ft | 94 Site 3 0-4 ft | 94 Site 3 4-8 ft |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NAPHTH | 0.054 | 0.044 | 0.13 | 0.21 | 0.16 | 0.24 | 0.23 | 0.054 | 0.11 | 0.11 | 0.067 | 0.075 |
| ACENAY | <0.48 | <0.48 | <0.50 | <0.46 | <0.47 | <0.44 | <0.44 | <0.47 | <0.47 | <0.44 | <0.49 | <0.44 |
| ACENAP | <0.48 | <0.48 | 0.051 | 0.050 | <0.47 | 0.044 | 0.035 | <0.47 | <0.47 | <0.44 | <0.49 | <0.44 |
| FLUORE | 0.031 | 0.026 | 0.096 | 0.093 | 0.048 | 0.079 | 0.072 | <0.47 | <0.47 | <0.44 | <0.49 | <0.44 |
| PHENAN | 0.22 | 0.21 | 0.52 | 0.60 | 0.36 | 0.40 | 0.36 | 0.21 | 0.30 | 0.27 | 0.19 | 0.22 |
| ANTRAC | 0.046 | 0.040 | 0.19 | 0.16 | 0.087 | 0.13 | 0.10 | 0.047 | 0.065 | 0.073 | 0.041 | 0.059 |
| FLANTHE | 0.29 | 0.31 | 0.77 | 0.78 | 0.42 | 0.70 | 0.52 | 0.37 | 0.39 | 0.43 | 0.32 | 0.34 |
| PYRENE | 0.32 | 0.35 | 0.83 | 0.78 | 0.49 | 0.69 | 0.53 | 0.39 | 0.40 | 0.48 | 0.37 | 0.36 |
| CHRYSE | 0.28 | 0.27 | 0.62 | 0.56 | 0.45 | 0.61 | 0.42 | 0.31 | 0.39 | 0.39 | 0.26 | 0.28 |
| BAANTHR | 0.18 | 0.18 | 0.45 | 0.41 | 0.32 | 0.47 | 0.31 | 0.20 | 0.24 | 0.26 | 0.17 | 0.18 |
| BBFLANT | 0.20 | 0.19 | 0.41 | 0.28 | 0.30 | 0.32 | 0.20 | 0.26 | 0.37 | 0.33 | 0.20 | 0.19 |
| BKFLANT | 0.20 | 0.15 | 0.32 | 0.29 | 0.21 | 0.32 | 0.20 | 0.27 | 0.25 | 0.23 | 0.20 | 0.21 |
| BAPYRE | 0.17 | 0.16 | 0.37 | 0.33 | 0.26 | 0.42 | 0.25 | 0.27 | 0.29 | 0.29 | 0.19 | 0.18 |
| I123PYR | 0.14 | 0.15 | 0.29 | 0.27 | 0.25 | 0.31 | 0.18 | 0.20 | 0.23 | 0.21 | 0.14 | 0.14 |
| DBAHANT | 0.045 | 0.036 | 0.097 | 0.068 | 0.081 | 0.093 | 0.052 | 0.050 | 0.075 | 0.071 | <0.49 | 0.045 |
| B-GHI-PY | 0.17 | 0.12 | 0.33 | 0.26 | 0.26 | 0.32 | 0.20 | 0.21 | 0.29 | 0.26 | 0.16 | 0.16 |
| 2MeNAPH | 0.049 | 0.030 | 0.090 | 0.10 | 0.082 | 0.074 | 0.061 | <0.47 | 0.064 | 0.048 | <0.49 | 0.056 |
| 2FLBP-S | 57.4% | 59.1% | 67.4% | 67.0% | 62.2% | 67.5% | 66.3% | 53.0% | 56.2% | 57.8% | 73.9% | 68.1% |

## Table 4
## Toledo Harbor CPF Cell 1 PCB Concentrations 1994-1995 (mg/kg)

| Parameters | 94 Site 1 0-4 ft | 95 Site 1 0-3 ft | 94 Site 1 4-8 ft | 95 Site 1 3-6 ft | 95 Site 1 6-9 ft | 94 Site 1 8-12 ft | 95 Site 1 9-12 ft | 94 Site 2 0-4 ft | 94 Site 2 4-8 ft | 94 Site 2 8-12 ft | 94 Site 3 0-4 ft | 94 Site 3 4-8 ft |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PCB-1016 | <0.029 | <0.028 | <0.030 | <0.027 | <0.028 | <0.026 | <0.027 | <0.15 | <0.15 | <0.15 | <0.15 | <0.15 |
| PCB-1221 | <0.029 | <0.028 | <0.030 | <0.027 | <0.028 | <0.026 | <0.027 | <0.15 | <0.15 | <0.15 | <0.15 | <0.15 |
| PCB-1232 | <0.029 | <0.028 | <0.030 | <0.027 | <0.028 | <0.026 | <0.027 | <0.15 | <0.15 | <0.15 | <0.15 | <0.15 |
| PCB-1242 | <0.029 | <0.028 | <0.030 | <0.027 | <0.028 | <0.026 | <0.027 | <0.15 | <0.15 | <0.15 | <0.15 | <0.15 |
| PCB-1248 | 0.064 | 0.063 | 0.133 | 0.133 | 0.116 | 0.134 | 0.159 | 0.044 | 0.074 | 0.103 | 0.046 | 0.049 |
| PCB-1254 | <0.029 | <0.028 | <0.030 | <0.027 | <0.028 | <0.026 | <0.027 | 0.018 | 0.038 | 0.050 | 0.019 | 0.023 |
| PCB-1260 | <0.029 | <0.028 | <0.030 | <0.027 | <0.028 | <0.026 | <0.027 | <0.15 | <0.15 | <0.15 | <0.15 | <0.15 |

## Table 5
## Toledo Harbor CPF Cell 1 Metal Concentrations 1994-1995 (mg/kg)

| Parameters | 94 Site 1 0-4 ft | 95 Site 1 0-3 ft | 94 Site 1 4-8 ft | 95 Site 1 3-6 ft | 95 Site 1 6-9 ft | 94 Site 1 8-12 ft | 95 Site 1 9-12 ft | 94 Site 2 0-4 ft | 94 Site 2 4-8 ft | 94 Site 2 8-12 ft | 94 Site 3 0-4 ft | 94 Site 3 4-8 ft |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arsenic | 8.16 | 8.20 | 9.19 | 8.77 | 9.34 | 7.37 | 6.92 | 8.08 | 8.14 | 8.38 | 7.52 | 8.11 |
| Cadmium | 0.30 | 1.40 | 2.50 | 1.70 | 1.80 | 2.40 | 1.50 | 1.40 | 2.00 | 1.60 | 1.10 | 1.30 |
| Chromium | 35.90 | 33.20 | 53.50 | 43.60 | 42.60 | 36.00 | 27.10 | 33.60 | 40.40 | 39.20 | 29.90 | 31.20 |
| Copper | 35.80 | 35.70 | 47.20 | 41.50 | 41.20 | 36.70 | 28.50 | 36.20 | 42.00 | 39.00 | 34.50 | 35.00 |
| Lead | 41.60 | 41.20 | 55.80 | 55.50 | 46.30 | 41.40 | 34.10 | 40.40 | 47.70 | 42.10 | 33.30 | 33.30 |
| Mercury | 1.74 | 1.78 | 2.26 | 2.49 | 1.94 | 2.28 | 2.30 | 2.20 | 2.46 | 1.76 | 3.06 | 3.06 |
| Nickel | 34.70 | 35.90 | 42.50 | 41.10 | 38.80 | 33.20 | 27.70 | 35.20 | 38.40 | 36.40 | 33.60 | 33.20 |
| Zinc | 189.00 | 171.00 | 193.00 | 234.00 | 159.00 | 127.00 | 96.20 | 164.00 | 192.00 | 159.00 | 159.00 | 169.00 |

The expected/predicted chemical composition of the manufactured topsoil is shown in Table 6. Total metal concentrations in the manufactured topsoil will be a fraction of the concentrations allowed for unrestricted land use for land receiving biosolids from reconditioned sewage sludge according to the USEPA's Part 503 regulations guidance (Table 6) (USEPA 1995). Soil fertility analysis and physical characteristics of proprietary Blend 4 are shown in Table 7.

**Table 6**
**Predicted Metal Concentrations in Bland 4 Using 0-3 ft Surface Layer of Dredged Material From Toledo Harbor Cell 1 (mg/kg)**

| Parameter | Dredged Material from Cell 1 | Blend 4 | EPA 503 Regulations |
|---|---|---|---|
| Arsenic | 8.20 | 5.00 | 41.00 |
| Cadmium | 1.40 | 0.84 | 39.00 |
| Chromium | 33.20 | 19.90 | |
| Copper | 35.70 | 21.40 | 1500.00 |
| Lead | 41.20 | 24.70 | 300.00 |
| Mercury | 1.78 | 1.07 | 17.00 |
| Nickel | 35.90 | 21.50 | 420.00 |
| Zinc | 171.00 | 102.60 | 2800.00 |

**Table 7**
**Soil Fertility Analysis and Physical Characterization of Blend 4 Consisting of Dredged Material From Cell 1**

| Parameters | Blend 4 Prior to Plant Growth Test | Blend 4 After Plant Growth Test |
|---|---|---|
| Total Kjeldahl Nitrogen, mg/kg | 319.0 | 157.0 |
| Total Phosphorus, mg/kg | 140.86 | 278.61 |
| Ortho-Phosphate, mg/kg | 15.80 | 4.56 |
| Sulfur, mg/kg | 619.50 | 462.74 |
| Magnesium, mg/kg | 210.30 | 195.15 |
| Sodium, mg/kg | 79.84 | 35.84 |
| Calcium, mg/kg | 2867.73 | 5782.46 |
| Zinc, mg/kg | 16.19 | 10.15 |
| Potassium, mg/kg | 260.94 | 229.84 |
| Organic Matter | 21.83 | 20.00 |
| CEC (Me/100g) | 57.7 | 56.8 |
| pH | 7.22 | 8.42 |
| Base Saturation % (Ca-Mg-K-Acid) | 84-10-4-2 | 93-5-2-0 |
| Particle Size | | |
| Sand % | 18.90 | |
| Silt % | 58.98 | |
| Clay % | 22.12 | |
| Note: Blend 4 consists of dredged material + cellulose + biosolids. | | |

## Seed Germination Screening Test, Toledo Harbor Dredged Material Cell 1

Figure 10 shows an overall view of the seed germination study after 14 days. Results of the seed germination tests are presented in Table 8. An evaluation of the ANOVA indicated that seed germination was influenced by treatment ($P=0.0001$), species ($P=0.0001$), and time ($P=0.01$). There was also a treatment-species interaction ($P=0.0001$). Generally, the best overall seed germination was observed in Blend 2, which consisted of dredged material from Cell 1, cellulose, and N-Viro biosolids ($P<0.05$) (Table 8). Even though Blend 2 showed the best percent germination overall, ryegrass percent seed germination in Blends 3 and 1 was significantly higher ($P<0.05$). However, seed germination values from Blend 5 (control) were significantly higher than all blends containing dredged material from Toledo Harbor Cell 1 (Table 8). For example, tomato seed germination was 77 percent in Blend 2 compared to 83 percent in Blend 5, while marigold seed germination was 77 percent in Blend 2 compared to 93 percent in Blend 5. Only 3 percent of vinca seeds germinated in Blend 2 compared to 40 percent in Blend 5. Seed germination was in the order of ryegrass > marigold > tomato > vinca.

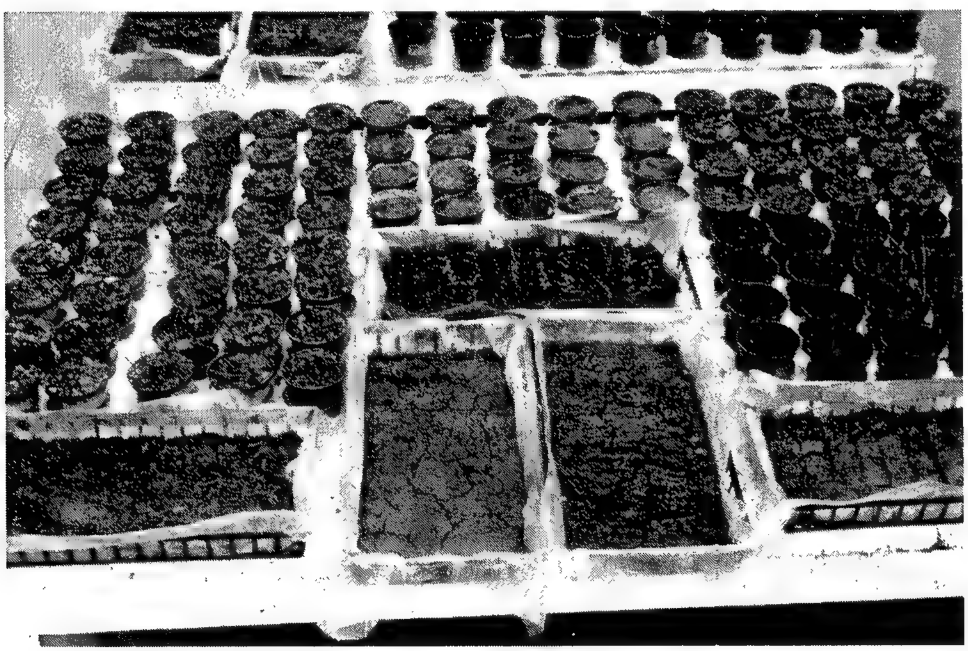

Figure 10. Overall view of the seed germination test using dredged material from Toledo Harbor Cell 1 CPF as the primary ingredient in the manufactured topsoil blends

**Table 8**
**Seed Germination From Manufactured Soil Using Toledo Harbor Dredged Material From Cell 1**

| Blend | Tomato[1] | | Marigold[1] | | Ryegrass[1] | | Vinca[1] | |
|---|---|---|---|---|---|---|---|---|
| | 14 Days % ± S.E. | 21 Days % ± S.E. | 14 Days % ± S.E. | 21 Days % ± S.E. | 14 Days % ± S.E. | 21 Days % ± S.E. | 14 Days % ± S.E. | 21 Days % ± S.E. |
| 5 (control) | 83.3 ± 2.4a | 86.7 ± 2.4a | 93.3 ± 2.3a | 93.3 ± 2.3a | 91.7 ± 7.1a | 91.7 ± 1.2a | 40.0 ± 7.1a | 60.0 ± 8.2a |
| 4 | 6.7 ± 2.4c | 10.0 ± 4.1c | 26.7 ± 2.4d | 30.0 ± 4.1c | 68.3 ± 9.4c | 70.0 ± 0.0b | 0.0 ± 0.0b | 0.0 ± 0.0c |
| 3 | 10.0 ± 4.1c | 26.7 ± 6.2b | 63.3 ± 8.5c | 76.7 ± 8.5b | 80.0 ± 0.0b | 91.7 ± 1.2a | 3.3 ± 2.3b | 3.3 ± 2.3c |
| 2 | 76.7 ± 8.5b | 86.7 ± 2.4a | 76.7 ± 9.5b | 93.3 ± 2.4a | 80.7 ± 1.2b | 86.7 ± 3.1a | 3.3 ± 2.3b | 23.3 ± 5.3b |
| 1 | 0.0 ± 0.0d | 13.3 ± 4.7c | 6.7 ± 4.7e | 10.0 ± 7.1d | 80.0 ± 5.8b | 90.7 ± 7.1a | 0.0 ± 0.0b | 3.3 ± 3.3c |

[1] Different letters indicate that values among blends and within species are significantly different at $P<0.05$ (Duncan's multiple range test).

Results after 21 days paralleled results obtained in the 14-day seed germination test. The additional time did, however, significantly enhance seed germination ($P<0.05$). For example, in Blend 2 after 21 days, tomato showed a 10 percent increase in germination, marigold showed an increase of 16 percent, ryegrass increased 7 percent, and vinca had the largest increase of 20 percent. Ryegrass seed germination in Blends 3 and 1 increased 5 and 9 percent, respectively. This additional time allowed the seed to imbibe water and swell, bursting the seed coat, thereby allowing the seeds to germinate. Ryegrass seed germination was significantly higher than other plant species. This suggests that ryegrass seed may be more efficient in taking up water. In addition, it may also show that ryegrass seed may be able to complete germination at lower water contents than tomato, marigold, and vinca.

The movement of water from dredged material to seeds, followed by uptake, is essential for seed germination (Bewley and Black 1985). Therefore, differences observed in seed germination among the different blends could be due to factors affecting the rate and extent of water movement from the manufactured soil blend to the seeds. For example, blends containing higher amounts of dredged material showed significantly lower seed germination (Table 8). This may be ascribed to the high degree of soil compaction or bulk density of the dredged material. Dredged material, with its high bulk density, decreased capillary water and vapor movement toward the seed, which in turn could have resulted in decreased imbibition or could have physically restricted the swelling of the seed, thus impeding seed germination (Hagon and Chan 1977). High bulk density decreases soil aeration, which may also impede seed germination (Hagon and Chan 1977).

## Plant Growth Screening Test, Toledo Harbor Dredged Material Cell 1

Figure 11 shows an overall view of the greenhouse growth test at 7 weeks. Visual observations as to leaf color, size and shape, and total aboveground biomass were used to evaluate the effects of the different Toledo Harbor dredged material Cell 1 blends on plant growth. Total aboveground biomass was influenced by treatment ($P=0.0001$) and species ($P=0.0001$). There was also a

treatment-species interaction effect on total aboveground biomass (P=0.0001). An evaluation of the total aboveground biomass revealed that the best plant growth overall was in Blend 4, consisting of dredged material from Cell 1, cellulose, and N-Viro biosolids (P<0.05) (Figure 12).

Figure 11. Overall view of the Toledo Harbor dredged material plant growth test at 7 weeks

Tomato and ryegrass grew better in Blend 4 than in Blends 2, 3, or 1 (Table 9; Figure 12). For example, tomato plants growing in Blend 4 had a significantly higher aboveground yield than the biomass yield obtained from Blends 2 and 3 (Figures 12a and 13). Blend 4, vegetated with tomatoes, obtained a final total aboveground biomass of 1.01 g compared to 0.09 g in Blend 2, and 0.58 g in Blend 3 (Table 9). It is also important to note that there was no significant difference between total aboveground biomass obtained from Blend 4 and the total aboveground biomass from Blend 5, the fertile reference control (Table 9; Figures 13, 14, 15, and 16). Tomato aboveground biomass from Blend 4 was 1.01 g compared to 0.95 g in Blend 5, the fertile reference soil (Table 9). Marigold grown in Blend 4 had a total aboveground oven-dry biomass of 0.66 g compared to 0.67 g in Blend 5 (Table 9). There was no significant difference among marigold biomass yield from Blends 3, 4, and 5 (Table 9). Even though overall plant aboveground biomass harvested from Blend 4 for all plants was significantly higher than the other blends, ryegrass biomass obtained from Blend 3 was not significantly different than biomass harvested from Blend 4. For example, total aboveground biomass yield for ryegrass from Blend 4 was 2.5 g compared to 1.7 g from Blend 5 (control), which was significantly higher, but not significantly different than biomass yield from Blend 3, which was 2.27 g (Table 9) (Figures 12c and 15). Vinca total aboveground biomass from Blend 4 was 0.02 g compared to 0.04 g from Blend 5 (Figures 12d and 16).

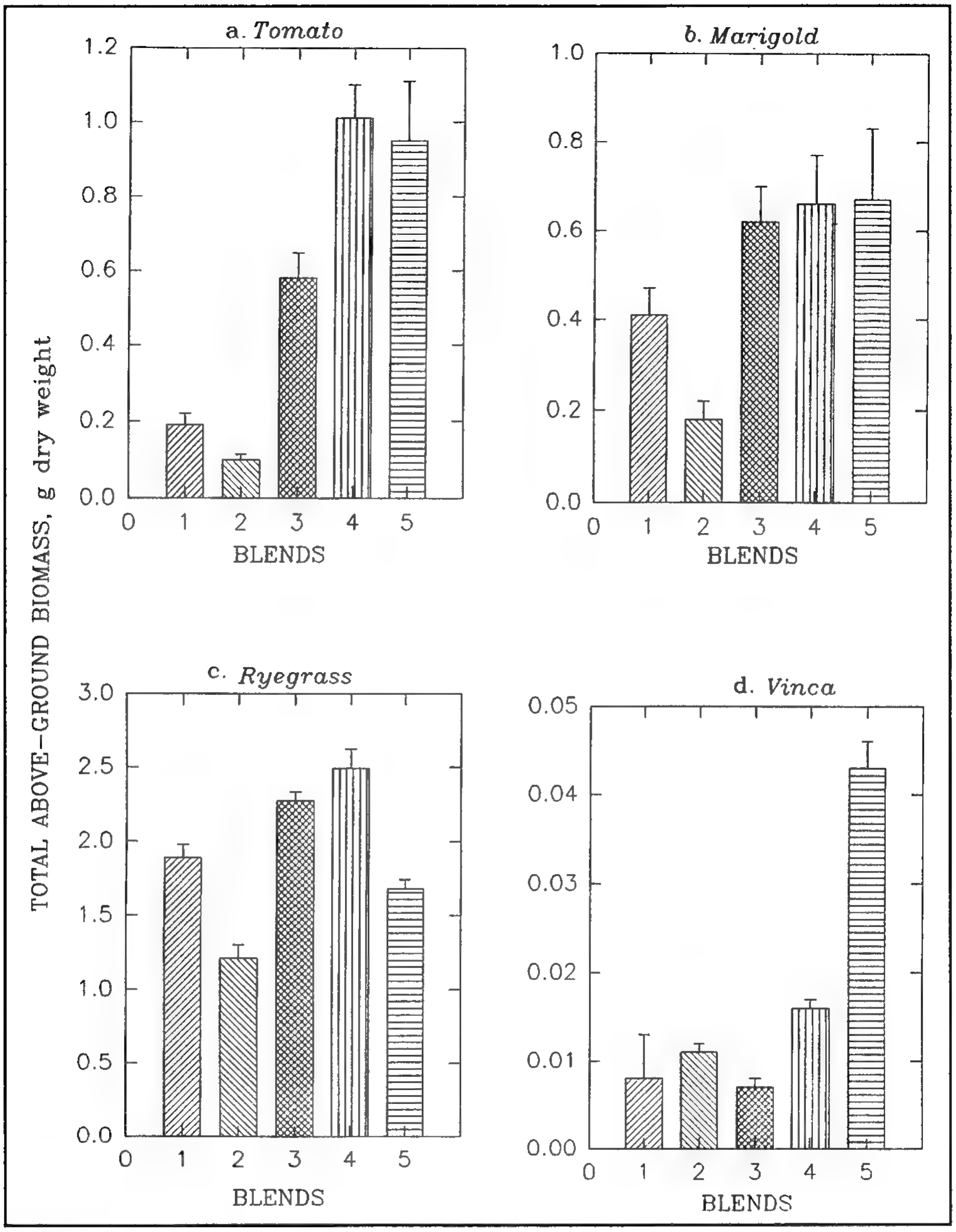


Figure 12. Total aboveground plant biomass from the various Toledo Harbor dredged material blends

Figure 13. Tomato plants growing in the various Toledo Harbor dredged material blends at 7 weeks (l to r, Blends 1, 4, 3, 2, and 5)

Figure 14. Marigold plants growing in the various Toledo Harbor dredged material blends at 7 weeks (l to r, Blends 2, 3, 4, 1, and 5)

Figure 15. Ryegrass plants growing in the various Toledo Harbor dredged material blends at 7 weeks (l to r, Blends 1, 4, 3, 2, and 5)

Figure 16. Vinca plants growing in the various Toledo Harbor dredged material blends at 7 weeks (l to r, Blends 2, 3, 4, 1, and 5)

**Table 9**
**Aboveground Biomass From the Toledo Harbor Dredged Material Manufactured Soil Test**

| | Tomato[1] | | Marigold[1] | | Ryegrass[1] | | Vinca[1] | |
|---|---|---|---|---|---|---|---|---|
| Blend | Fresh Wt, g | Dry Wt, g | Fresh Wt, g | Dry Wt, g | Fresh Wt, g | Dry Wt, g | Fresh Wt, g | Dry Wt, g |
| 5 (control) | 13.74a | 0.95a | 6.62a | 0.67a | 15.25b | 1.68b | 0.35a | 0.04a |
| 4 | 11.47a | 1.01a | 6.10a | 0.66a | 21.14a | 2.50a | 0.17b | 0.02b |
| 3 | 6.46b | 0.58b | 6.50a | 0.61a | 20.26a | 2.27a | 0.17b | 0.01b |
| 2 | 1.13c | 0.09c | 1.63c | 0.18c | 10.13c | 1.21b | 0.08c | 0.02b |
| 1 | 2.27c | 0.19c | 3.53b | 0.41b | 16.52b | 1.89b | 0.07c | 0.01b |

[1] Different letters indicate that values among blends and within species are significantly different at $P<0.05$ (Duncan's multiple range test).

Visual observations, during the first 2 weeks, of leaf color, size, and shape revealed similarities between plants growing in Blend 4 and those growing in Blend 5, the fertile reference soil. However, at day 21, plant growth in Blend 4 seemed slower than in Blend 5. Leaf color gradually changed from green to yellow, and leaves were not as broad as those of plants growing in Blend 5. Yellow color and narrow leaves were ascribed to nutrient deficiency in the manufactured soil blend as a result of plants depleting nitrogen and other nutrients in the blend. On day 22, soluble ammonium-nitrate and Miracle Gro™ (13N-13P-13K) were added to all of the Toledo Harbor dredged material blends to increase the manufactured topsoil fertility. The addition of nutrients to the blends appeared to have enhanced plant growth. At the end of 7 weeks, visual observations of leaf color and plant size and shape revealed similarities between plant species growing in Blend 4 and plant species growing in Blend 5, the fertile reference soil (Figures 13, 14, 15, and 16).

# 5 Conclusions and Recommendations

## Conclusions

The results from Phase 1 of the manufactured topsoil bench-scale screening tests conducted at ERDC, Vicksburg, MS, indicated that Blend 4, consisting of Toledo Harbor dredged material from Cell 1, cellulose, and N-Viro biosolids, will enhance plant growth. Proprietary Blend 4 appears very promising as a manufactured topsoil product that may be used for landscaping. The results from Scott and Sons Company screening test (Appendix A) also showed that Toledo Harbor dredged material from Cell 1 may be used as an ingredient for Scott and Sons Company bagged soil product. Therefore, it is concluded that a high-quality manufactured soil product could be blended using Toledo Harbor dredged material from Cell 1.

## Recommendations

It was recommended that the manufactured soil product containing Toledo Harbor dredged material from Cell 1, cellulose, and N-Viro biosolids be demonstrated in a Phase 2 pilot-scale field study at Toledo, OH. Interested parties, such as the City of Toledo, Port Authority, University of Toledo, and Toledo Botanical Gardens, who were willing to cooperate in such a demonstration were contacted. During the summer of 1996, a field demonstration was successfully conducted that produced 550 cu yd of fertile topsoil. This manufactured topsoil was used to landscape the entrance to the University of Toledo and improve soil beds at the entrance of the Toledo Botanical Gardens. Commercialization of this recycled soil manufacturing technology has been initiated for Toledo, OH.

# References


Bewley, J. D., and Black, M. (1985). *Seeds: Physiology of development and germination.* Plenum Press, New York.

Hagon, M. W., and Chan, C. W. (1977). "Soil moisture stress and germination," *Aust. J. Biol. Sci.* 17, 86-89.

SAS Institute, Inc. (1994). *SAS/STAT user's guide Version 6, Volume 2.* 4th ed., Gary, NC.

U.S. Environmental Protection Agency. (1989). "Development of risk assessment methodology for land application and distribution and marketing of municipal sludge," EPA/600/6-89/001, U.S. Environmental Protection Agency.

__________. (1990). "Technical support documentation for Part I of the National Sewage Sludge Survey Notice Availability," Analysis and Evaluation Division, U.S. Environmental Protection Agency, Washington, DC.

__________. (1993). "Standards for the use or disposal of sewage sludge; Final rules," 40 CFR Part 503 et al. *Fed Reg.* 58(32), 9248-9415.

__________. (1995). "A guide to the biosolids risk assessments for the EPA Part 503 Rule," EPA/832-B-93-005, Office of Wastewater Management, U.S. Environmental Protection Agency, Washington, DC.

Water Resources Development Act. (1992). Washington, DC.

# Appendix A
# Summary of Results From Scott and Sons Company Screening Test

The results of the screening test conducted by Scott and Sons Company is presented in Table A1.

**Table A1**
**Results From Scott and Sons Company Screening Test**

| Seed Germination Test | | | | | | |
|---|---|---|---|---|---|---|
| Blend | Germination % | | | Quality (1 to 10) | | |
| | Ryegrass | Marigold | Tomato | Ryegrass | Marigold | Tomato |
| 1 - PS | 83 | **85** | 75 | 6.0 | 5.0 | 5.0 |
| 2 - PS | 75 | 70 | 80 | 5.0 | 4.5 | 4.5 |
| 3 - PS | **88** | **90** | 75 | **7.0** | 5.5 | **6.0** |
| 4 - RM | **90** | **85** | 80 | 5.5 | 5.0 | 5.0 |
| 5 - PS | 88 | 80 | 80 | 6.5 | 6.0 | 5.5 |
| Plant Growth Test | | | | | | |
| Blend | Color (1 to 10) | | | Quality (1 to 10) | | |
| | Tomato | Marigold | Vinca | Tomato | Marigold | Vinca |
| 1 - PS | 6.8 | 6.8 | 3.4 | **6.8** | 5.6 | 3.2 |
| 2 - PS | **7.0** | 6.6 | 2.6 | **6.8** | 5.6 | 2.0 |
| 3 - PS | 5.8 | 6.2 | 4.0 | **6.0** | **6.4** | 3.2 |
| 4 - RM | 5.8 | 6.0 | **5.0** | 5.2 | 5.4 | 3.6 |
| 5 - PS | 7.0 | 7.2 | 4.4 | 5.8 | 6.0 | 4.4 |
| | Fresh Weight, g | | | | | |
| Blend | Tomato | Marigold | Vinca | | | |
| 1 - PS | **10.61** | 5.54 | 0.31 | | | |
| 2 - PS | **10.63** | 5.0 | 0.20 | | | |
| 3 - PS | **11.59** | **7.77** | 0.27 | | | |
| 4 - RM | 9.45 | 5.29 | 0.40 | | | |
| 5 - PS | 7.36 | 4.86 | 0.42 | | | |

Note: Bold values are equal to or greater than control reference (Blend 5).
RM = Toledo Harbor raw material.
PS = Potting soil.

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U.S. Army Engineer Research and Development Center
Environmental Laboratory
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Dyntel Corporation
3530 Manor Drive, Suite 4
Vicksburg, MS 39180

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**14. ABSTRACT**
Soil particles and other materials in runoff find their way to the bottom of waterways. These soil particles become sediment that eventually has to be removed from the waterways to maintain navigation. The U.S. Army Corps of Engineers is responsible for maintaining the Nation's navigable waterways and annually dredges approximately 400 million cubic meters of sediment. A small volume of this dredged material contains a wide range and level of contaminants such as polynuclear aromatic hydrocarbons, polychlorinated biphenyls, pesticides, and metals. Dredged material that cannot pass stringent open-water disposal testing criteria requires confined disposal alternatives. Finding disposal sites for dredged material is becoming difficult, since most confined disposal facilities (CDFs) are at full capacity. Likewise, sewage sludge can no longer be disposed of in the ocean; consequently, sewage sludge is accumulating on land at many sewage-treatment facilities. Also, large volumes of sewage sludge are currently placed in landfills; however, landfills are filling at accelerated rates. To resolve the accumulation and disposal of sewage sludge, the U.S. Environmental Protection Agency has issued 40 CFR Part 503 regulations. The 503 regulations promote the reuse of biosolids derived from sewage sludge and establish maximum limits for metals in soils amended with biosolids derived from sewage sludge for agricultural production. The recycled soil manufacturing technology offers a quick, simple, low-technology, effective, and affordable means of allowing the reuse of dredged material, provides additional placement capacity for future dredged material by emptying many existing full CDFs, and recycles waste materials to the benefit of the American people.

**15. SUBJECT TERMS**

| | | |
|---|---|---|
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| Cellulose | Manufactured topsoil | Screening tests |
| | Plant growth | Seed germination |

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